National Aeronautics and
Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Reply to Attn of: EI42 (FA2007-002) October 25, 2006

TO: EI42-Sverdrup/Jim Blanche

FROM: EI42/Patrick McManus

SUBJECT: Joint Committee on Aircraft Aging/Joint Group on Pollution Prevention (JCAA/JGPP) Lead-free Solder Study (JN06-017 thru JN06-019)

The EI42/EEE Parts Engineering & Analysis Team conducted a failure analysis study to assist the JCAA/JGPP committee with locating failure sites in components assembled on a variety of boards exposed to harsh environments. The boards were shipped from different teams and consisted of vibration, mechanical shocked, and thermally shocked boards. EI42 analyzed parts identified by the committee, uncovered damage sites, and provided data back to the committee. The data consisted of images from cross sections and radiography and accounted for almost 5 gigabytes of file space. The data was provided to Jim Blanche on three separate DVD's. A brief report describing the study is attached.

Original signed by

Patrick D. McManus
Lead, EEE Parts Engineering & Analysis Team

cc:
EI42/Mark Strickland/Jeff Brown

Analysts:
EI42/Terry Rolin, Ph.D./Amanda Hoover
EI42-Sverdrup/Garry McGuire

Attachment

Project: Joint Committee on Aircraft Aging/Joint Group on Pollution Prevention (JCAA/JGPP) Lead-free Solder Study

Date Completed: October 23, 2006

Job Numbers: JN06-0017, JN06-018, JN06-019

Analysts: Terry D. Rolin, Ph.D. and Amanda Hoover
Microscopy and Analysis
EI42/EEE Parts Engineering & Analysis Team

Garry McGuire
IR Thermography
EI42/Electronic Fabrication & Test Team

Synopsis

Jim Blanche of the EI42/Electronic Fabrication & Test Team requested that the EI42/EEE Parts Engineering & Analysis Team conduct a failure analysis study to assist the JCAA/JGPP committee with locating failure sites in components assembled on a variety of boards exposed to harsh environments. The boards were shipped from different teams and consisted of vibration, mechanical shocked, and thermally shocked boards. The boards contained several different kinds of components as well as a variety of solder and solder finishes. It was beyond the scope of EI42's study to evaluate the reliability and failure mechanisms of the various boards and finishes. EI42's sole objective was to look at the parts identified by the committee, uncover damage sites, and provide data back to the committee. The data consisted of images from cross sections and radiography and accounted for almost 5 gigabytes of file space.

Procedure

The boards that were delivered to EI42 had been exposed to three different environments including vibration, mechanical shock, and thermal shock. The level of exposure was inconsequential to EI42's objective and is not reported here. EI42 received three boards from each environment given a total of nine different boards. The analysis plan shown in Figures 1-6 illustrates the parts that were examined, how they were examined, and how file naming conventions were established. Figure 7 illustrates how each part's lead or ball is numbered. The parts were removed from the boards using a high-speed Dremel cutting tool. They were then labeled and potted in a two part epoxy (Buehler Epo-resin and Epo-hardener) and allowed to harden overnight without heat or pressure. Grinding was accomplished by the following technique: 240 grit, 400 grit, 800 grit, and 1200 grit. This was followed by polishing using 6 micron diamond and 0.05 micron alumina.

Analysis

Analysis consisted of performing optical microscopy, radiography, and thermal imaging (where applicable) of the various parts to determine which ones should be analyzed. When determinations were made that anomalies clearly existed, the parts were removed from the boards and cross sectioned. Table 1 is provided to the reader to distill the large amount of data gathered during this study and summarizes the types of failures found during the analysis. Figures 8-12 show the basic types of anomalies found, namely; ball to pad interface fractures (Figure 8), copper trace fractures (Figure 9), lead to solder fractures (Figure 10), voiding (Figure 11) and poor solder wetting (Figure 12). Failure analysis was not conducted on some of the parts either at the request of the customer or because no anomalies were identified during optical microscopy and radiography. This was done in order to focus and expedite the data acquisition.

Vibration				Mechanical				Thermal			
Part Type	Board 8	Board 77	Board 118	Part Type	Board 28	Board 98	Board 136	Part Type	Board 82	Board 158	Board 162
BGA U4	Fractures found in traces and ball/Cu interfaces	Fractures found in traces and ball/Cu interfaces	Fractures found in traces and ball/Cu interfaces	PDIP U30	Lead to solder fractures found	Lead to solder fractures found	Lead to solder fractures found	BGA U2	No fractures found	Fractures at ball/Cu interface only	No FA
BGA U5	Fractures found in traces and ball/Cu interfaces	Fractures found in traces and ball/Cu interfaces	Fractures found in traces and ball/Cu interfaces	CLCC U14	Optical and radiography looked good, no FA	Optical and radiography looked good, no FA	Optical and radiography looked good, no FA	BGA U5	No FA	No FA	No FA
BGA U43	Fractures found in traces and ball/Cu interfaces	Fractures found only in balls	Fractures found in traces and ball/Cu interfaces	IO P1	Lead to solder fractures found	Lead to solder fractures found	Lead to solder fractures found	BGA U21	No FA	No FA	No FA
				IO P2	No FA	No FA	Lead to solder fractures found	TQFP U3	No FA	Major fractures in lead to solder interface with poor wetting	No FA
				BGA U43	Fractures found in traces and ball/Cu interfaces	Fractures found in traces and ball/Cu interfaces	Fractures at ball/Cu interface only	TQFP U57	No FA	Small fractures at heels but overall good connectivity	No FA

Table 1. Quick glance table identifying board components and the types of anomalies found in those components during the failure analysis.

Summary

Ball interface and trace fractures were found in every part identified as failed. The level of fracturing varied from environment to environment, board to board, and part to part. A detailed reliability study is beyond the scope of this study's objective. However, sufficient data has been generated to greatly assist the JCAA/JGPP committee in conducting the reliability study. The data was provided to Jim Blanche on three separate DVD's. There were cases where no analysis was conducted.

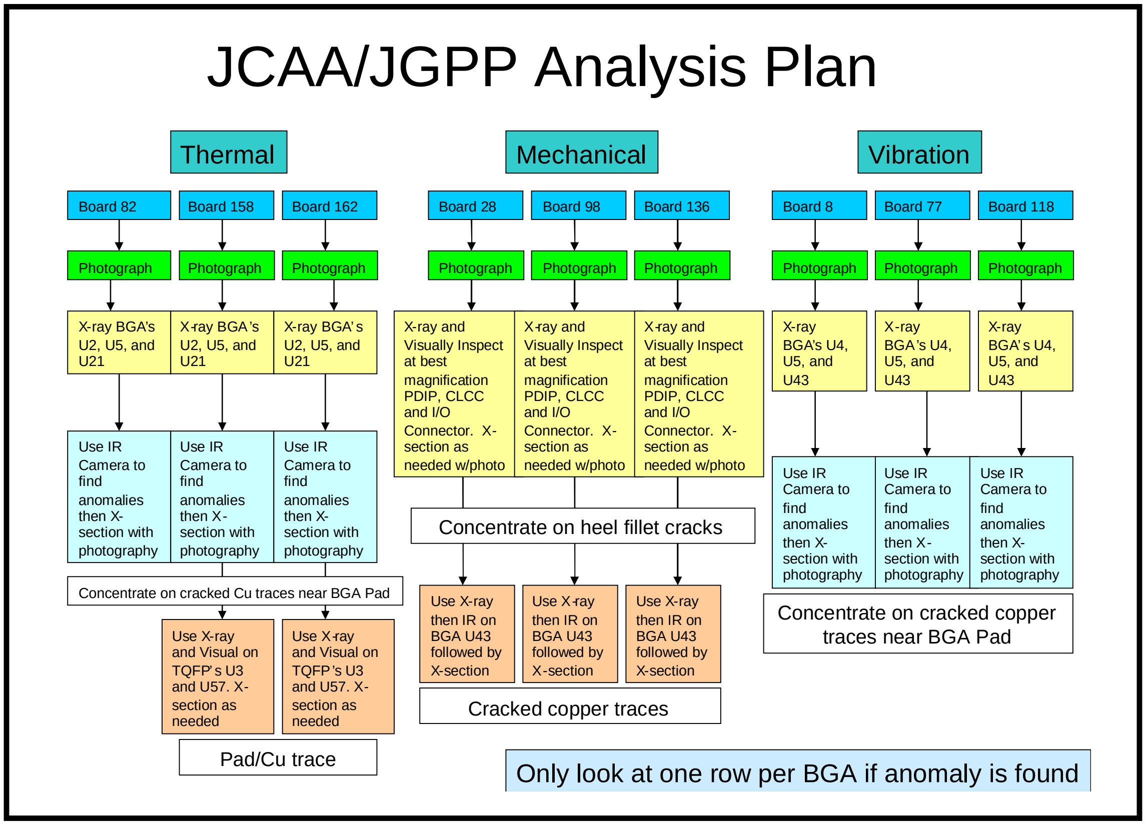

Figure 1. High level plan showing types of analyses to conduct per board type and finish.

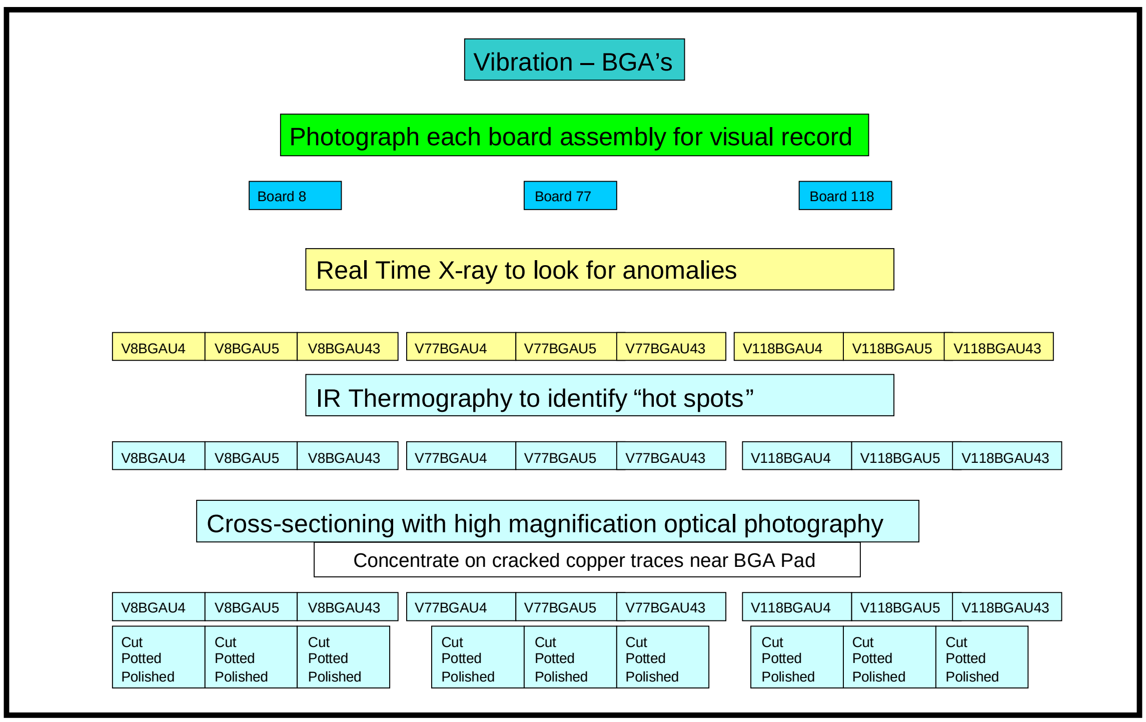

Figure 2. Analysis plan and file naming convention for BGA components from vibration boards.

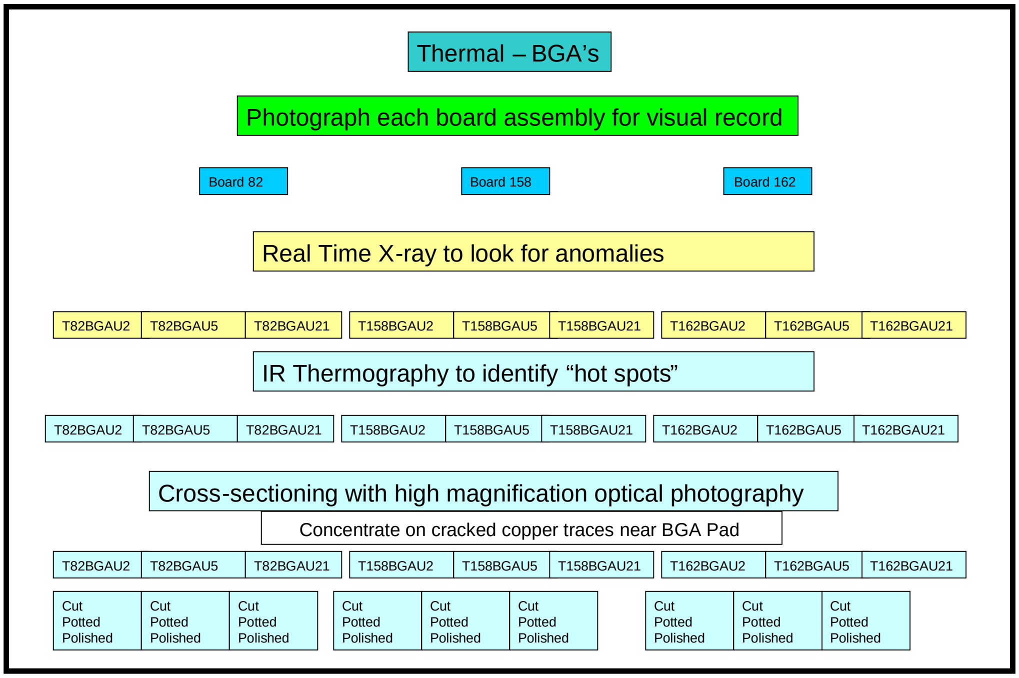

Figure 3. Analysis plan and file naming convention for BGA components from Thermal boards.

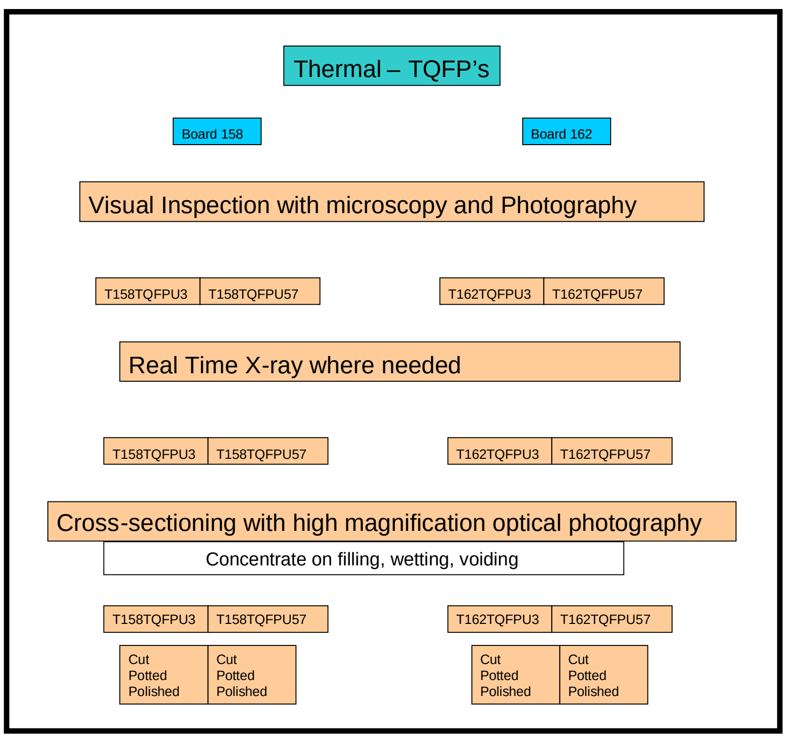

Figure 4. Analysis plan and naming convention for flat pack components from Thermal boards.

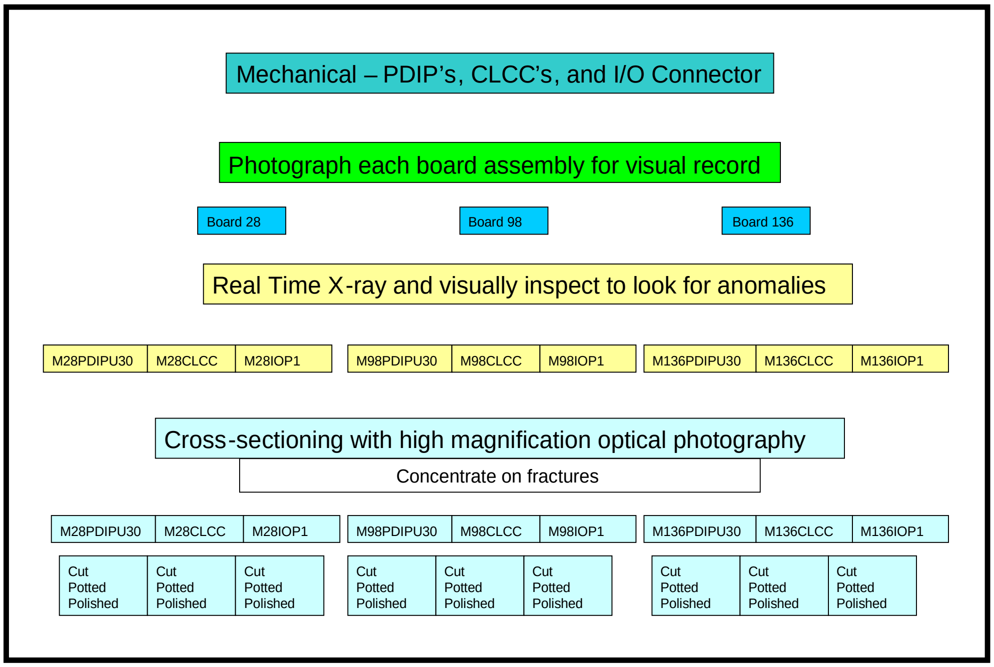

Figure 5. Analysis plan and naming convention for various components from the Mechanical shock boards.

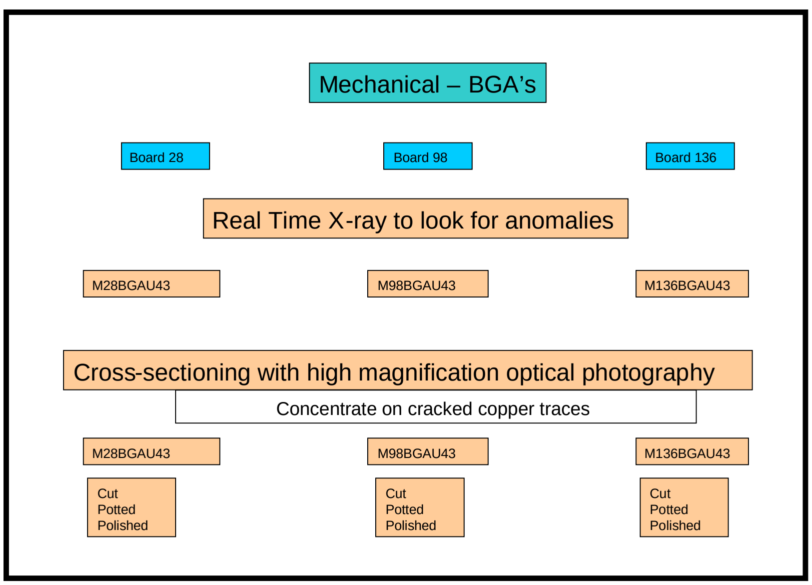

Figure 6. Analysis plan and naming convention for specific BGA components from the Mechanical shock boards.

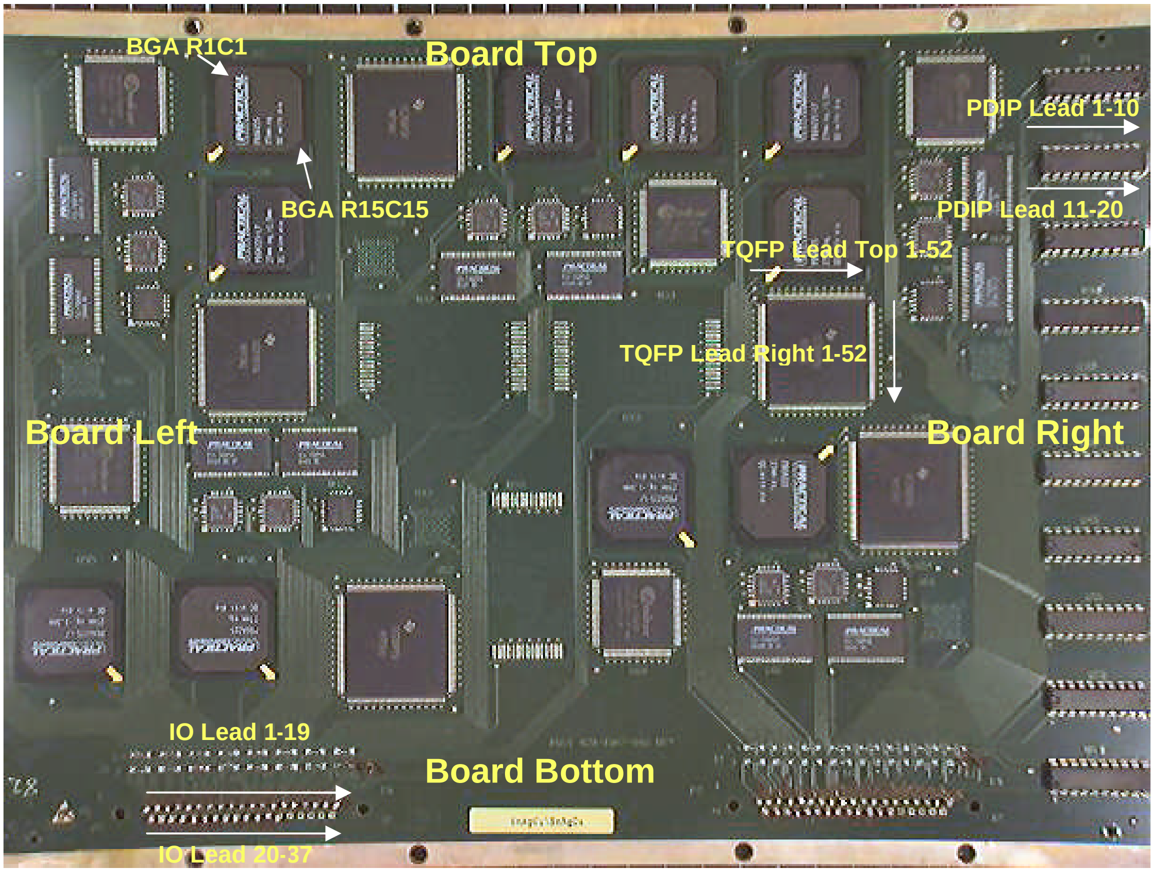

Figure 7. Overall board image used to illustrate the naming/numbering convention used for part leads and BGA balls.

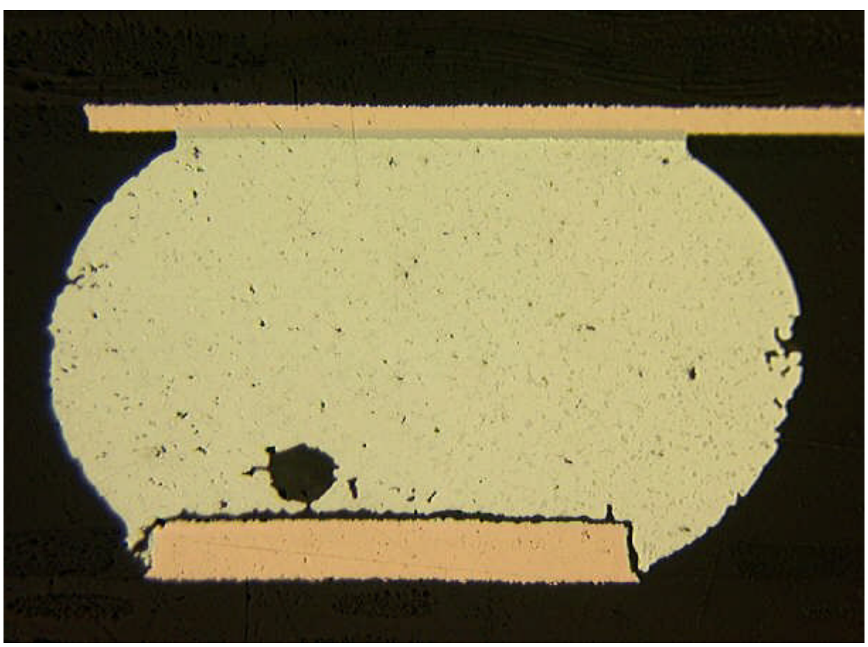

Figure 8. Ball to pad interface fracture in component BGA U2 from Thermal Board 158.

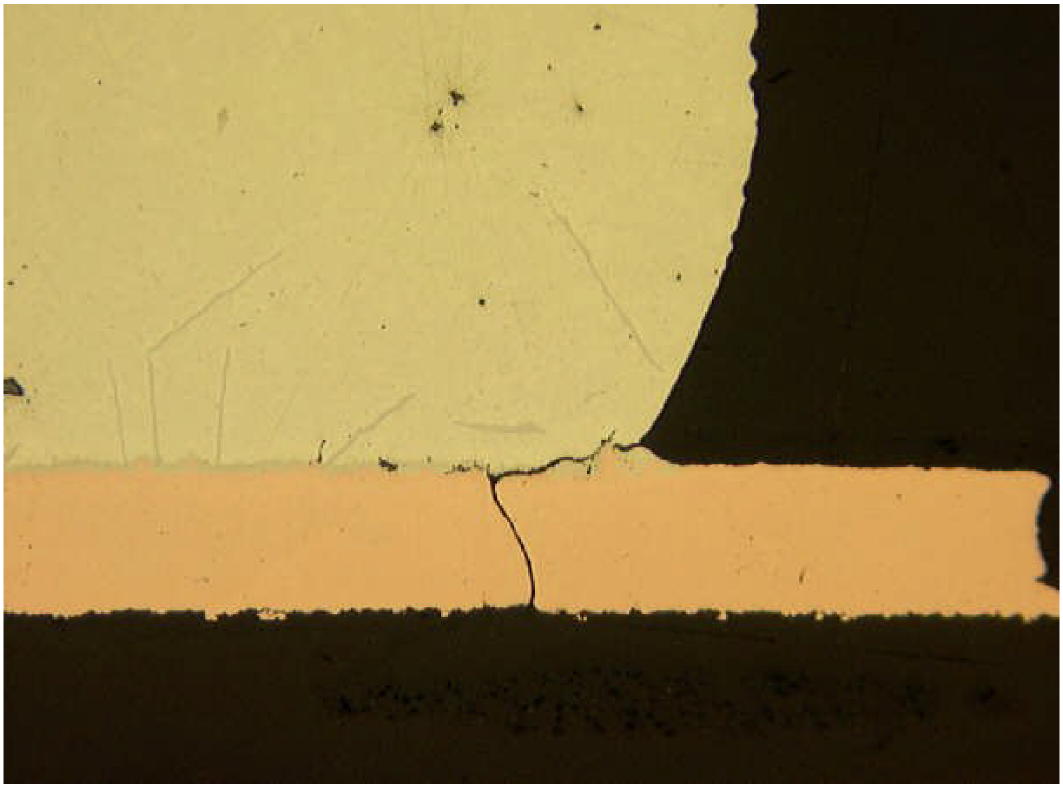

Figure 9. Copper trace fracture in component BGA U43 from Mechanical Shock Board 98.

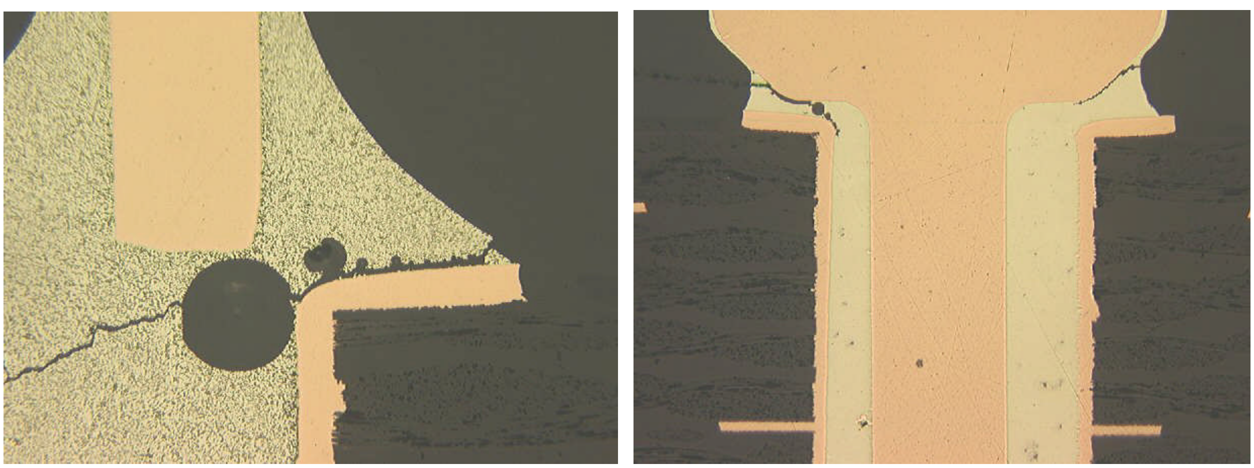

Figure 10. Lead to solder fracture in component PDIP U30 from Mechanical Shock Boards 28 and 136, respectively.

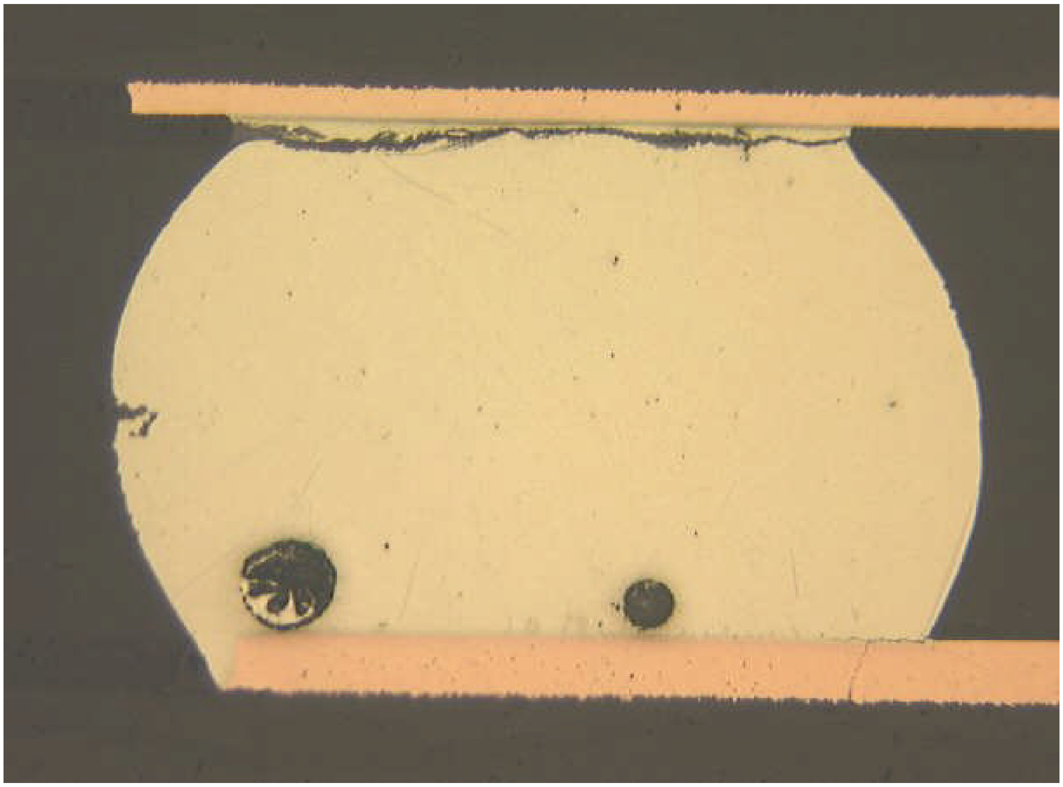

Figure 11. Ball interface fracturing, trace fracturing, and voiding in component BGA U4 from Vibration Board 77.

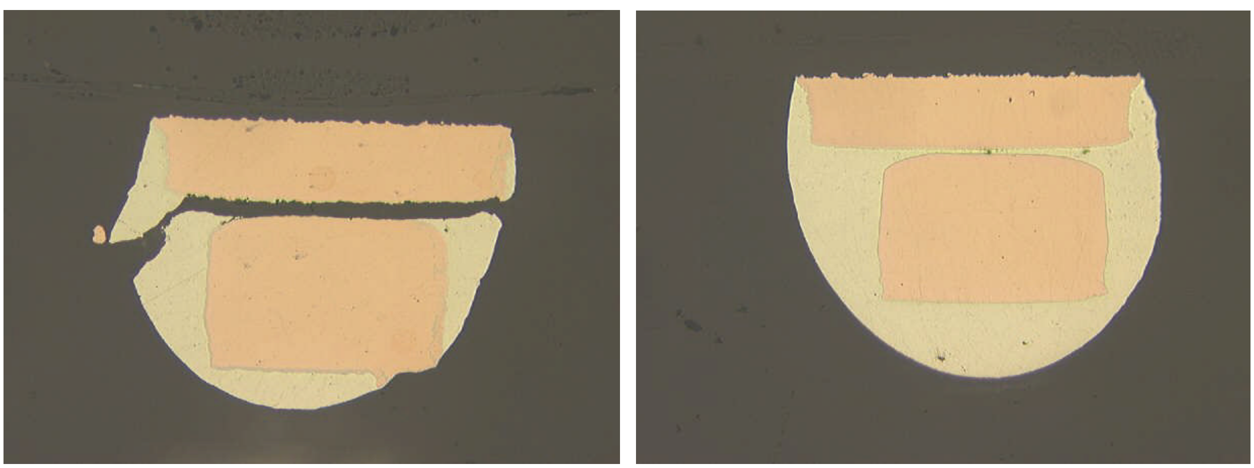

Figure 12. Lead to pad interface fracturing and poor wetting found in component TQFP U3 from Thermal Board 158 (left) compared to good characteristics in component TQFP U57 from the same board (right).